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## Severe hemoptysis: From diagnosis to embolization



A. Khalil<sup>a,b,\*,c</sup>, B. Fedida<sup>a,e</sup>, A. Parrot<sup>d</sup>, S. Haddad<sup>a,e</sup>,  
M. Fartoukh<sup>d,e</sup>, M.-F. Carette<sup>a,e</sup>

<sup>a</sup> Department of radiology, Tenon Hospital, 75020 Paris, France

<sup>b</sup> Department of radiology, Bichat Hospital, 46, rue Henri Huchard, 75018 Paris, France

<sup>c</sup> Paris VII University, 75205 Paris cedex 13, France

<sup>d</sup> Department of Intensive Care, Tenon Hospital, 75020 Paris, France

<sup>e</sup> Paris VI University, 75252 Paris cedex 05, France

### KEYWORDS

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**Abstract** Severe hemoptysis is life-threatening to patients because of the asphyxia it causes. The diagnosis and treatment are therefore urgent and chest imaging is essential. Multidetector CT-angiography provides an exhaustive non-invasive assessment which includes localization, mechanisms, causes and severity of the hemoptysis. It is an invaluable step in preparation for endovascular treatment which is the first line invasive therapy, particularly with bronchial arteriography embolization in the majority of cases (over 90%) and erosion or rupture of the pulmonary artery in less than 10% of cases. Hemoptysis control is achieved in 65 to 92% of cases depending on the cause.

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Hemoptysis is the exteriorization of red aerated blood from the mouth following a cough originating from below the glottis. It represents blood from the thoracic vascular sector passing into the respiratory sector. Hemoptysis is a common symptom in respiratory medicine. It accounts for 10 to 15% of the reasons for consultation in hospital respiratory department and is a warning signal for investigation into its cause [1,2]. Severe hemoptysis (SH) is life-threatening and has a mortality rate of over 50% without control of the bleeding [3,4]. It requires rapid and simultaneous management for both diagnostic (mechanism and cause) and therapeutic [5] purposes. Endovascular management, especially embolization of the bronchial arteries, is now the 1st line treatment [5] to control the bleeding. The

\* Corresponding author.

E-mail address: [antoine.khalil@yahoo.fr](mailto:antoine.khalil@yahoo.fr) (A. Khalil).

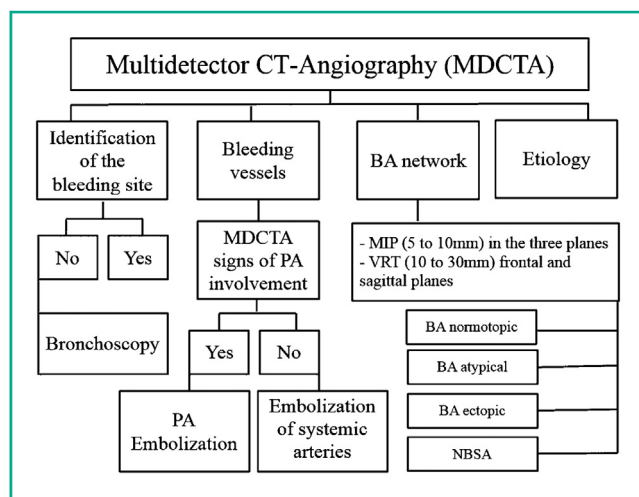
indications for endovascular treatment are unequivocal in hemoptysis which is causing concern because of its volume (over 200 mL/24–48 h), its consequences on the respiratory system (acute respiratory failure) or if the mechanism is potentially life-threatening (erosion of the pulmonary artery) [6].

The physician (ideally the intensive care physician) faced with a case of SH should ask him/herself five questions: is this actually hemoptysis? How severe is it? What is the site? What is its cause and most likely mechanism? What treatment should be given? Multidetector CT-angiography (MDCTA) can answer a number of these questions (Fig. 1) and is essential for the radiologist before considering interventional radiology [7,8].

## The use of CT angiography in severe hemoptysis

### Imaging technique

The investigation should be performed in deep inspiration if possible, failing which it should be performed in free respiration [9]. All of the intrathoracic blood vessels should be enhanced using a contrast injection rate (at a concentration of 300 mg of iodine/mL) of 3.5 to 4 mL/sec with a total volume of 90 mL. Image acquisition is triggered by a region of interest (ROI) in the descending aorta from 100 Hounsfield Units for 16-row CT-scan and 150 HU for a higher row CT-scan. Coverage should begin from the lung apices (C5–C6) to the hilum of the kidneys (L1–L2), from the supra-aortic vessels to the origin of the inferior diaphragmatic arteries. It is recommended that images be started at the base of the cranium in patients with a past history of neck surgery or radiotherapy for a nasopharyngeal cancer.



**Figure 1.** Interpretation algorithm and expected results of multidetector CT-angiography. MDCTA: multidetector CT-angiography; MIP: maximum intensity projection; VRT: volume rendering technique; PA: pulmonary artery; BA: bronchial artery; NBSA: non-bronchial systemic artery.

### Confirmation of the hemoptysis

In the majority of cases, the clinical enquiry will establish the origin of red blood coming from the mouth. Occasionally, a diagnosis is uncertain and MDCTA can therefore demonstrate a cause and/or signs of alveolar or bronchial flooding with intraluminal clots.

### Severity of the bleeding

In terms of severity, the volume of hemoptysis and respiratory consequences can clinically identify the majority of SH [6]. If the clinical enquiry however is unreliable, MDCTA may again offer assistance [7].

We have shown that the extent of parenchymal involvement on CT correlates with the magnitude of the bleed and with clinical severity. Involvement of more than 3 lobes is usually associated with exteriorized bleeding of over 200 mL/24–48 h and requires more interventionist treatment [10] even if the patient has not coughed up a large volume of blood (Fig. 2).

### Site of the bleed

Lateralization (the bleeding side) and precise localization of the hemoptysis are essential for treatment. When hemoptysis is causing asphyxia, simple selective protection of the respiratory tract can only be performed when the side of the bleeding is known. Similarly, some embolization decisions in situations at high risk of complication can only be considered if the side of the hemoptysis is known with certainty. The decision to perform surgery to stop bleeds can also only be made when there is certainty as to the lobe that is to be excised.

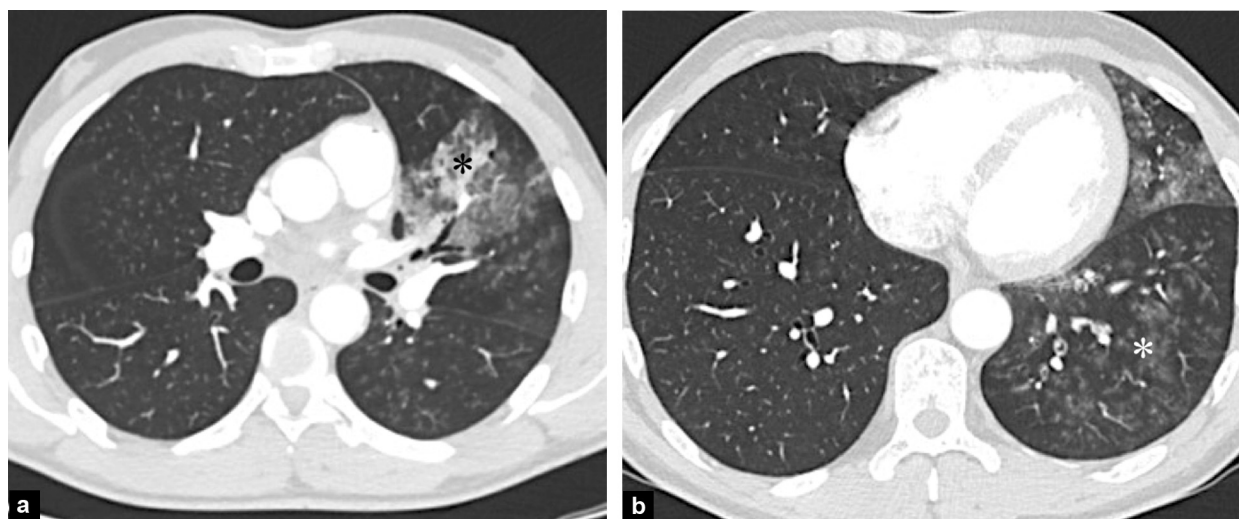
The bleed is localized from the parenchymal window investigation that seeks to identify aground glass opacity or alveolar consolidation (Fig. 3a,b). This abnormality is of high localizing value [10–12]. The presence of several areas of ground glass opacities and/or alveolar consolidation with a relatively unaffected subpleural area should suggest the possibility of intra-alveolar hemorrhage. If a ground glass opacity image is present in the bases together with an alveolar consolidation in the upper part of the lung (Fig. 2), the site of the bleeding is the highest part and the other abnormalities are due to positional flooding [12].

Some signs reflect the cause (bronchiectasis, cavitation or pulmonary artery pseudoaneurysm) or consequence of the bleeding (endobronchial clot) and have lower localizing value.

Lung consolidation with necrosis or cavitation associated with the appearance of a pulmonary artery pseudoaneurysm (an uncommon situation) indicates a bleed originating from the pulmonary artery (Fig. 4).

The topographic diagnostic yield of MDCTA compared to clinical assessment at the patient's bedside (including the clinical enquiry, clinical examination, chest radiography and bronchoscopy) is similar and in the region of 80% [7]. As a result, in our view, bronchoscopy can be delayed.

Bronchoscopy is no longer the first line investigation to locate the bleeding and is reserved for diffuse or bilateral



**Figure 2.** Severity of hemoptysis. a: axial CT-scan image: localized alveolar changes (asterisk) surrounded by ground glass opacities in the lingula, locating the bleeding to this area; b: axial CT-scan in the lung bases: nodular ground glass opacities (asterisk) indicating the extent of the hemoptysis and flooding of the lower lobe.

diseases for which MDCTA is not accurate to locate the bleeding site. The majority of patients will undergo bronchoscopy after the episode of bleeding, 4 to 6 days after endovascular treatment. In this situation, the yield of bronchoscopy is higher as it examines a clean bronchial tree (distant to the bleeding and without clots) and allows biopsies to be taken in a more settled environment after embolization.

### Cause of the bleeding

Hemoptysis has many causes (**Boxed text 1**). More than 2/3 of the cases of hemoptysis in France are due to three causes: active tuberculosis (**Fig. 5**) or complications of old tuberculosis (**Fig. 6**), bronchiectasis and lung cancer (**Fig. 7a–c**). Cryptogenic hemoptysis accounts for 20 to 30% of cases and is defined as hemoptysis with no cause found during the hospitalization and a negative assessment at 3 months including CT-scan and bronchoscopy (**Fig. 8**).

### Mechanism of the bleeding

The two major mechanisms responsible for hemoptysis are the systemic arteries (bronchial arteries and non-bronchial systemic arteries) in 90% of cases and the pulmonary arteries in under 10% of cases. MDCTA signs of systemic bleeding are indirect, whereas the MDCTA of pulmonary arterial involvement are direct [12]. When a MDCTA is requested for hemoptysis, bleeding from the pulmonary artery must firstly be excluded, looking for direct signs, although in some cases both mechanisms may be involved.

### Hemoptysis arising from the pulmonary artery

Less than 10% of all cases of hemoptysis originate from the pulmonary artery. The mechanism of this type of bleeding depends on the cause, and may be traumatic (Swan-Ganz catheter), inflammatory (Behçet's disease or Hughes-Stovin's syndrome), neoplastic (tumor necrosis and when the pulmonary artery is not encased in solid tumor), and infection. The most common causes

**Boxed text 1: Major causes of hemoptysis. Bronchiectasis, tumors, tuberculosis (acute and late complications) and cryptogenic causes account for over 80% of the causes of hemoptysis.**

A – Tumors

Malignant: lung cancer metastases

Benign: carcinoid tumor

B – Bronchiectasis

C – Infections

Tuberculosis, atypical Mycobacter infection

Chronic pulmonary aspergillosis

Invasive aspergillosis

Necrotizing pneumonias

Lung abscesses

D – Vascular

Pulmonary arterial aneurysms

Pulmonary sequestration

Arteriovenous malformation

Traumatic pulmonary artery pseudoaneurysm (Swan Ganz)

E – Vasculitis

Granulomatosis with polyangiitis (formerly Wegener's disease)

Behçet's disease and Hughes-Stovin syndrome

Takayashu's disease

F – Trauma

Post-traumatic hematoma

Post-traumatic fistula

Pulmonary erosion from a rib fragment

G – Cardiovascular abnormalities

Eisenmenger's syndrome

Mitral stenosis

Aortobronchial fistula

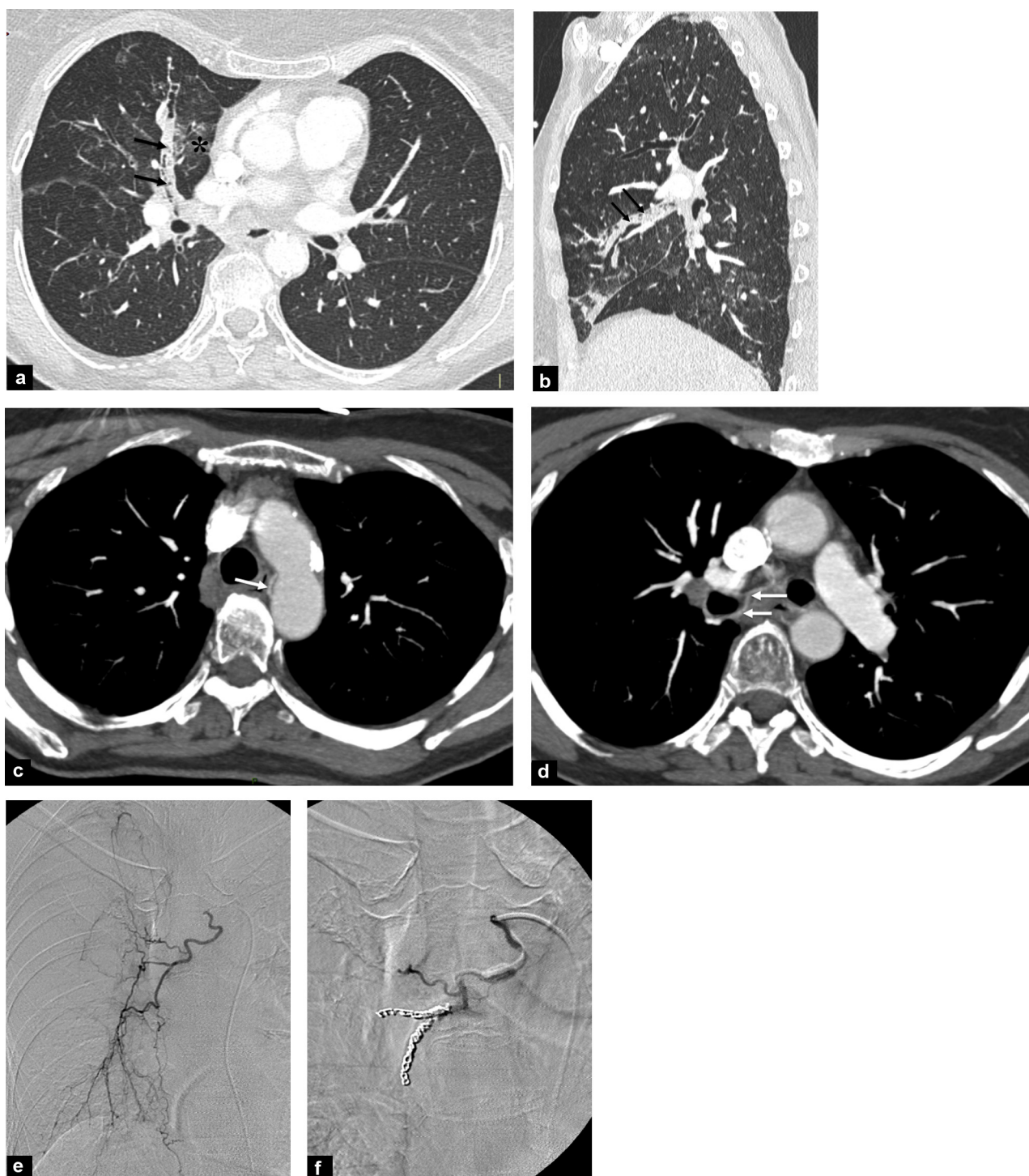
H – Bronchial circulation abnormality

Dieulafoy's syndrome

Bronchial artery hemangioma

I – Cryptogenic (no cause found)

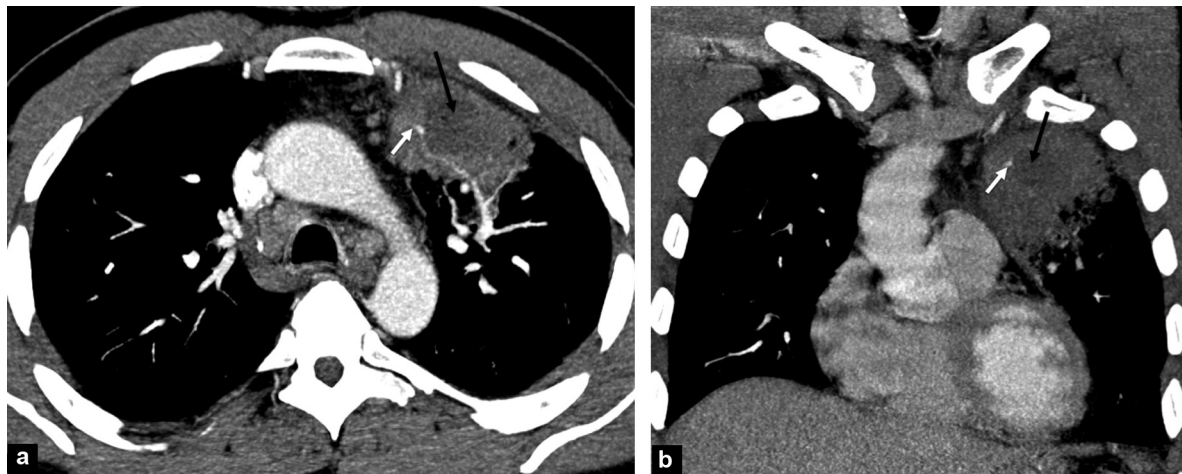




**Figure 3.** Hemoptysis associated with bronchiectasis. Forty-three-year-old female patient with no particular past history, transferred to intensive care for massive hemoptysis about 350 mL on one time. a: axial CT-scan image in the parenchymal window focused on the right middle lobe bronchus. Ground glass opacities (asterisk) with bronchiectasis fully filled with blood clots (black arrows); b: sagittal reconstruction image in the parenchymal window showing the bronchus fully filled with clots (black arrows) and distal consolidation in the right middle lobe. Note the increased density in the right lower lobe; c, d: axial CT-scan images passing through the aortic arch and infracarenal region. Bronchial vessel with an atypical origin arising from the aortic arch (arrows); e, f: bronchial angiography before (e) and after embolization with particles and occlusion with coils (f).

of infections are predominantly tuberculosis (Rasmussen aneurysm), necrotic infectious pneumonias and other infections involving parenchymal necrosis such as invasive aspergillosis.

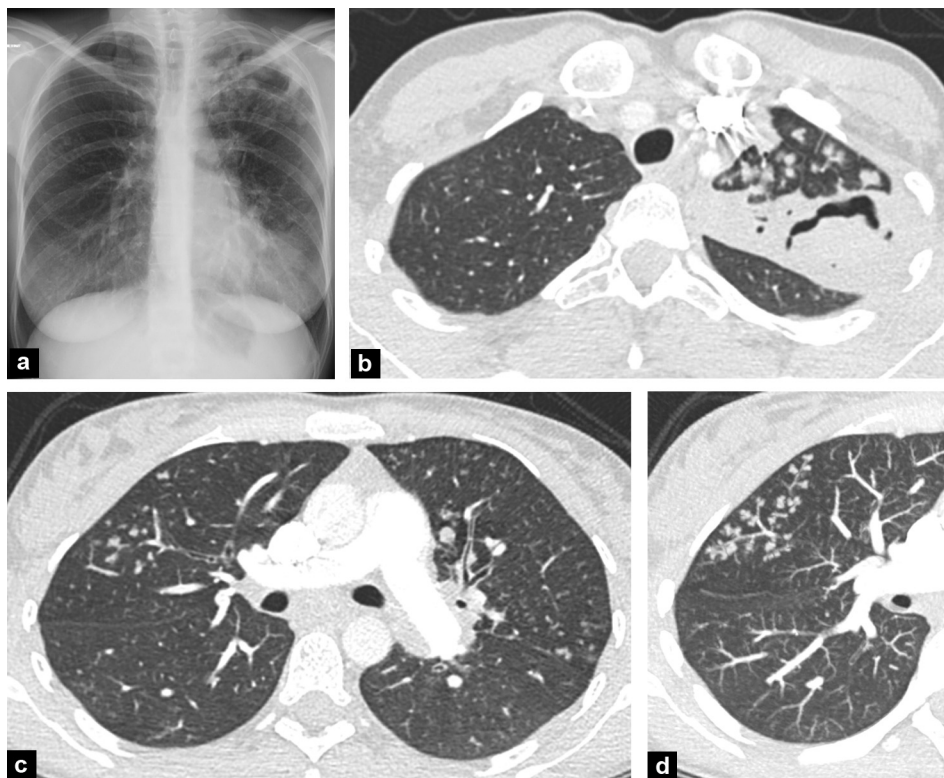
The MDCTA signs of pulmonary arterial involvement depend on the cause [13]. In systemic disease with pulmonary artery aneurysms, the pulmonary artery aneurysm at the origin of the bleeding is present within an area of



**Figure 4.** Necrotic pneumonia with a pulmonary artery pseudo-aneurysm. a, b: six mm maximum intensity projection, axial (a) and coronal (b) views showing lung consolidation of the ventral segment of the culmen with necrosis (black arrow) and ectasia (white arrow) of a branch of the pulmonary artery representing a pulmonary artery pseudo-aneurysm.

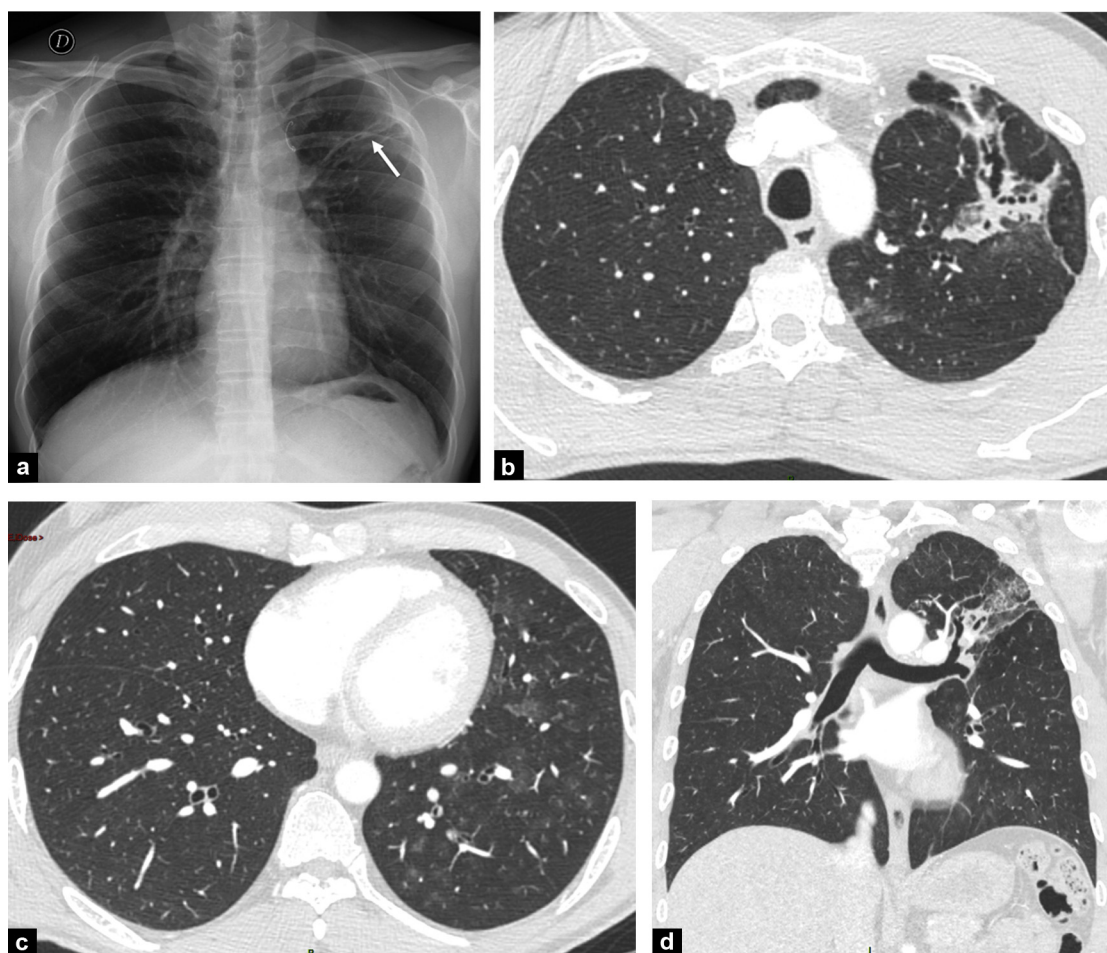
lung consolidation or ground glass opacity (Fig. 4). This aneurysm requires emergency treatment. The majority of other pulmonary artery aneurysms respond well to appropriate medical therapy.

In infectious disease, the main sign is necrosis which can be identified as a hypodense area within lung parenchymal consolidation which is enhanced by the iodinated contrast media. Late phase CT images or enhanced images can



**Figure 5.** Hemoptysis and active tuberculosis. Nineteen-year-old female patient presenting to the emergency department with hemoptysis. Clinical enquiry assessed the hemoptysis volume as being over 250 mL during the last 24 hours. a: postero-anterior chest radiograph (CXR): lung cavities in the left upper lobe with adjacent nodules, lung consolidation in the lingula and right axillary micronodular appearances; b: axial CT-scan passing through the apex confirming the CXR findings: cavernous appearance with nodules in the culmen; c: axial CT-scan view passing through the main trunk of the pulmonary artery: bilateral hilar lymphadenopathy predominantly on the left and infracarenal lymphadenopathy; d: axial CT-scan showing the tree-in-bud appearance (branch nodules) indicating bronchiolar spread of the disease. The diagnosis was confirmed to be active bacillary pulmonary tuberculosis responsible for hemoptysis for which embolization of the bronchial arteries achieved immediate control without recurrence.





**Figure 6.** Hemoptysis and late complications of tuberculosis. Fifty-three-year-old man hospitalized for hemoptysis of 300 mL over the previous 48 hours. a: postero-anterior chest radiograph: aerated atelectasis of the culmen with bronchiectasis (arrow) and raised left main bronchus; b: CT-scan image passing through the apices: traction bronchiectasis combined with adjacent lung consolidation and a ground glass opacity indicating the site of the hemoptysis; c: CT-scan image passing through the bases: nodules of increased density with ground glass opacity in the left lower lobe indicating the extent of the hemoptysis and flooding from the culmen; d: coronal reconstruction: good correlation with the chest radiograph. Raised left fissure with bronchiectasis in the culmen and increased ground glass opacity. A bronchial arteriography with embolization (in addition to antibiotic therapy) was carried out with no recurrence after a follow-up period of 6 months.

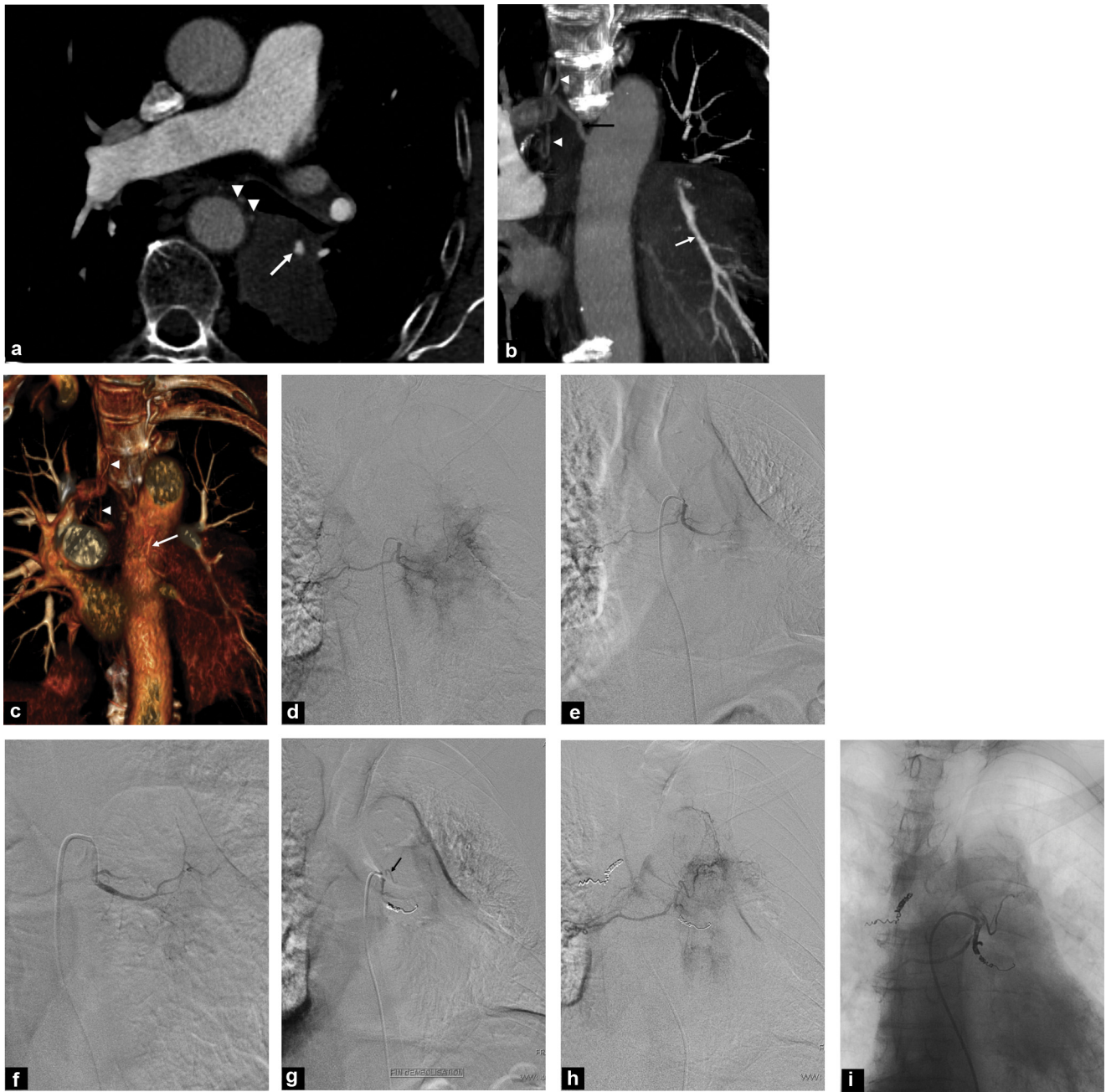
improve visibility of the hypodense area. The second sign is a pseudoaneurysm within the hypodense area. Investigation for a pseudoaneurysm is performed on 5 to 8 mm thick maximal intensity projection (MIP) reconstructions in the mediastinal window in all three spatial planes. A less specific sign is the presence of a pulmonary artery with irregular borders in the wall of the necrosis.

### Hemoptysis of systemic origin and mapping of systemic arteries

By excluding a pulmonary arterial mechanism, MDCTA allows a conclusion to be drawn that the hemoptysis has its origin in a systemic artery. MDCTA visualizes the bronchial arteries (BA) and the non-bronchial systemic arteries (NBSA) responsible for the bleeding. In addition, Remy-Jardin et al. [8] have shown that MDCTA is more accurate than conventional angiography in identifying the bronchial arteries. This difference is explained by anatomical variants and catheterization difficulties associated with patient age because

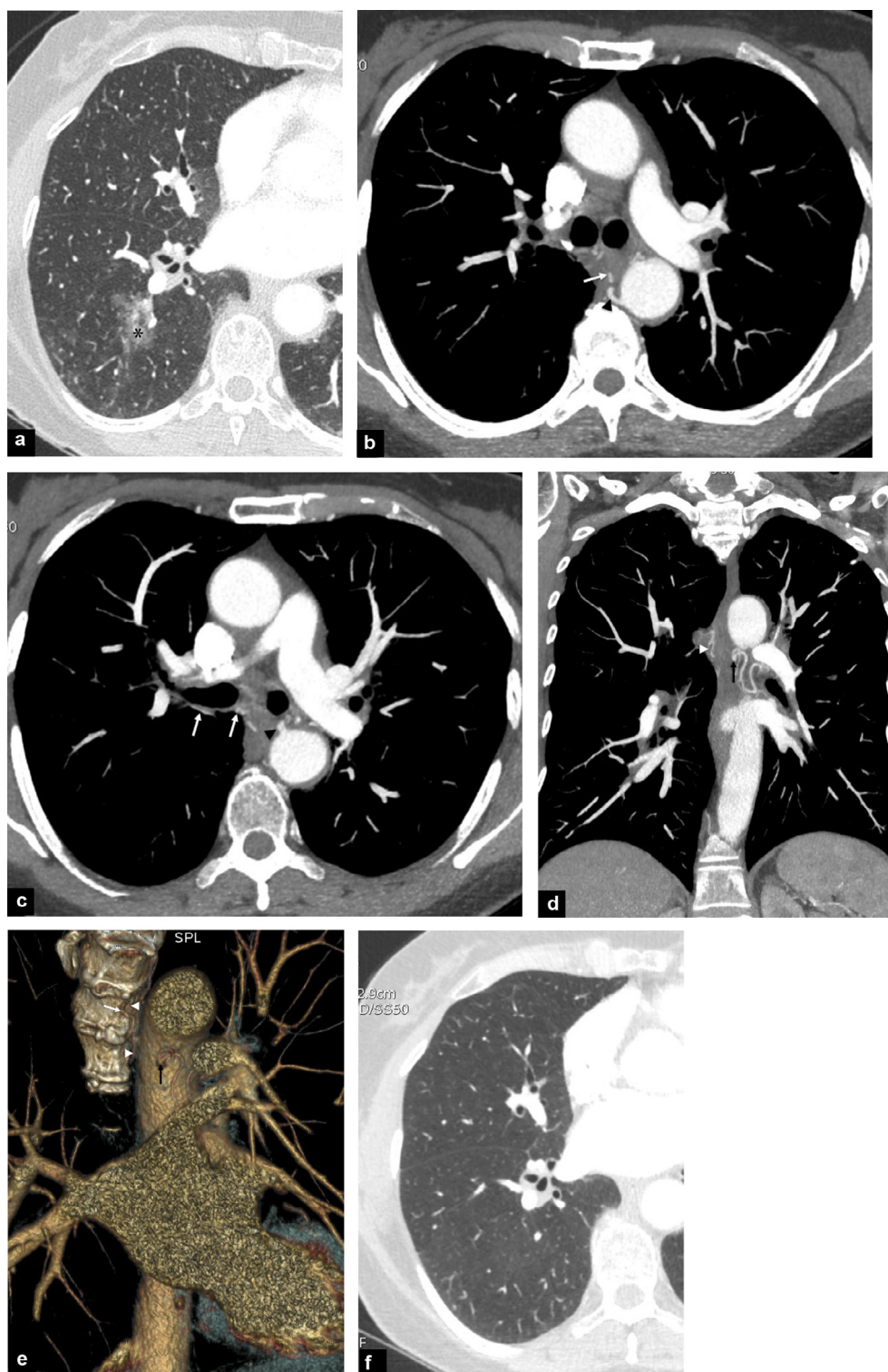
of atheromatous plaques. We have compared two groups of patients who underwent systemic arterial embolization or attempted embolization before and after the era of MDCTA; we included 200 patients in each group and divided the cohorts into 3 groups according to patient age (under 50 years old, 50 to 70 years old and over 70 years old) and compared the catheterization failure rate by age band in both cohorts (with and without MDCTA). The catheterization failure rates in the group of patients over 70 years old were 36.6% and 14.6% in the cohorts without and with MDCTA respectively. By expressing the failure rate as a ratio to the age band of patients between 50 and 70 years old, we found that the failure rate was almost stable when the procedure was preceded by MDCTA (14.6 compared to 12%), whereas it increased by a factor of almost 3.5 if MDCTA was not used (36.6 compared to 10.2%).

The use of Volume rendering technic (VRT) is more accurate (Fig. 7c) than axial images to detect ectopic arteries [9,14] and their path in the mediastinum.



**Figure 7.** Left lower lobe non-small cell lung cancer (squamous cell) with 40 mL/day hemoptysis for several weeks. The frequency and volume of the hemoptysis have increased recently. a: axial CT-scan image: showing stenosis of the pulmonary artery (arrow) by the tumor and hypertrophy of the left bronchial artery (arrowheads); b: coronal maximal intensity projection reconstruction of 12 mm thick slab showing a left hilar pulmonary mass surrounding the pulmonary artery (white arrow) and a hypertrophy of a broncho-intercostal trunk (black arrow) giving rise to a collateral right bronchial artery (arrowheads); c: coronal volume rendered technical reconstruction showing the right broncho-intercostal trunk with its right bronchial artery (arrowheads) and in particular the origin of a common right-left bronchial trunk (CRLBT; arrow) giving rise to the left vascularization and the right inferior bronchial artery; d: CRLBT angiogram showing left hilar hypervascularization with no systemic-pulmonary shunt; e: intermediary RLCBT repeat angiogram showing near complete devascularization of the tumor; f: RLCBT angiogram after hyper-selective catheterization with a Progreat 2.4-F (Terumo) microcatheter: persistent slight tumor parenchymography. Further embolization with Embosphere® 700 particles (CeloNova); g: repeat angiogram after occluding the left bronchial artery of the CRLBT with a Micro-Nester® 0.18 coil (COOK): permanent occlusion of the bronchial artery and opacification of a small superior collateral vessel (arrow). Because of the persistent hemoptyses with fresh blood in the region of 50 mL/day, the decision was taken to repeat the procedure; h: CRLBT angiogram showing vascularization with a neoplastic appearance at the start of the small collateral which was left patent in the first embolization; i: repeat after embolization with Onyx® HD18: satisfactory progression of the material with the microcatheter at the tip of the 5-F catheter. The hemoptysis stopped immediately.





**Figure 8.** Cryptogenic hemoptysis. Forty-five-year-old man presenting to respiratory department with hemoptysis. Clinical enquiry assessed the hemoptysis as being 100mL/24h. a: axial CT-scan image in the parenchymal window showing an area of increased density with focal ground glass opacity (asterisk) localizing the bleeding; b, c: axial CT-scan image in the mediastinal window: nodular or linear enhancement in the mediastinum representing the bronchial vessels in their mediastinal path; d: frontal reconstruction image in the mediastinal window showing the left bronchial trunk (black arrow) and bronchial artery (white arrowhead) of the right broncho-intercostal trunk; e: coronal image with volume rendered technical reconstruction showing the left bronchial trunk (black arrow), the right broncho-intercostal trunk (white arrow) and the right bronchial artery (white arrowheads) of this trunk; f: axial CT-scan image 1 month later showing disappearance of the increased density of ground glass appearance. Bronchoscopy, bacteriology samples and the immunology assessment were negative. The diagnosis made was that of cryptogenic hemoptysis (without cause).



Currently, the identification of the middle anterior spinal artery of the high thoracic spinal cord is only possible with conventional angiography (Fig. 9a–c).

The contribution to the bleeding from NBSA should be considered in chronic disease with a pleural symphysis. Yoon et al. showed that CT-scan offered excellent sensitivity and specificity and had a high diagnostic value in detecting NBSA [15,16]. The NBSA may contribute to hypervascularization and bleeding in chronic lung disease with pleural involvement.

Contribution from NBSA to the hypervascularization is unequivocal if systemic vessels pass through pleura that are over 3 mm thick.

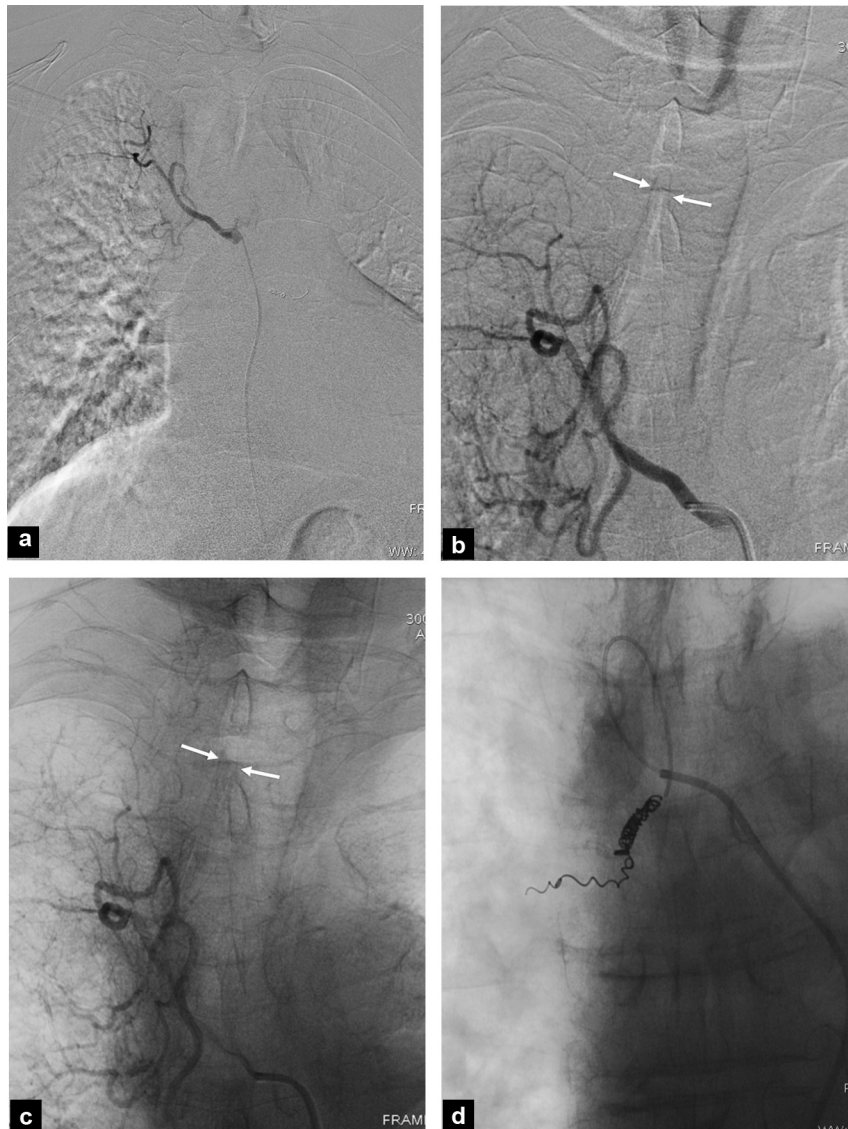
The NBSA most often found are:

- the intercostal arteries in posterior disease;

- branches of the subclavian arteries in the apices;
- the internal thoracic arteries in the anterosuperior segments;
- the triangular ligament arteries in the bases and paramediastinal region;
- the inferior diaphragmatic arteries in the bases;
- the coronary arteries in some diseases.

## Endovascular treatment of severe hemoptysis

Currently, this treatment can only be considered after an initial MDCTA assessment and in close collaboration with



**Figure 9.** Median anterior spinal artery at the cervicothoracic junction. a: angiogram of a right broncho-intercostal trunk showing the right superior bronchial artery; b, c: angiogram of the same artery magnified (subtracted “b” and unsubtracted “c”) centering on the cervicothoracic spine and showing a small narrow vessel leading towards the middle with a “hairpin” shape. This structure, which is slightly lateralized to the right because of slight rotation of the patient with respect to the X-ray beam, is the median anterior spinal artery supplying the cervicothoracic region of the spinal cord; d: use of a microcatheter with occlusion of the trunk using 3-F Micro-Nester® 0.18 coils (COOK; 2 mm in diameter and 7 cm long). Particles are formerly contra-indicated in this situation because of the large risk of accidental embolization as a result of reflux from the median anterior spinal artery.

intensive care or respiratory physicians and surgical team for overall management of the disease.

In our center, the indication for this treatment (Fig. 10) is based on the volume of the hemoptysis (over 200 mL/24–48 h), repercussions on oxygenation (acute respiratory failure) and on any pulmonary artery damage. Below 50 mL/24–48 h, endovascular management is not indicated and between 50 and 200 mL/24–48 h, the indication depends on the patient's underlying condition (poor respiratory reserve in patients with chronic respiratory failure) or causes such as aspergilloma with a high risk of recurrence as massive hemoptysis.

## Techniques, approaches and embolization materials

### Embolization of systemic arteries (BA and NBSA)

In the majority of situations, the approach is via the right femoral artery after inserting a 5-F introducer. We prefer to use long 5-F introducers (45 cm) in patients over 70 years old or in those with tortuous atheromatous arteries which makes navigation and catheterization more straightforward.

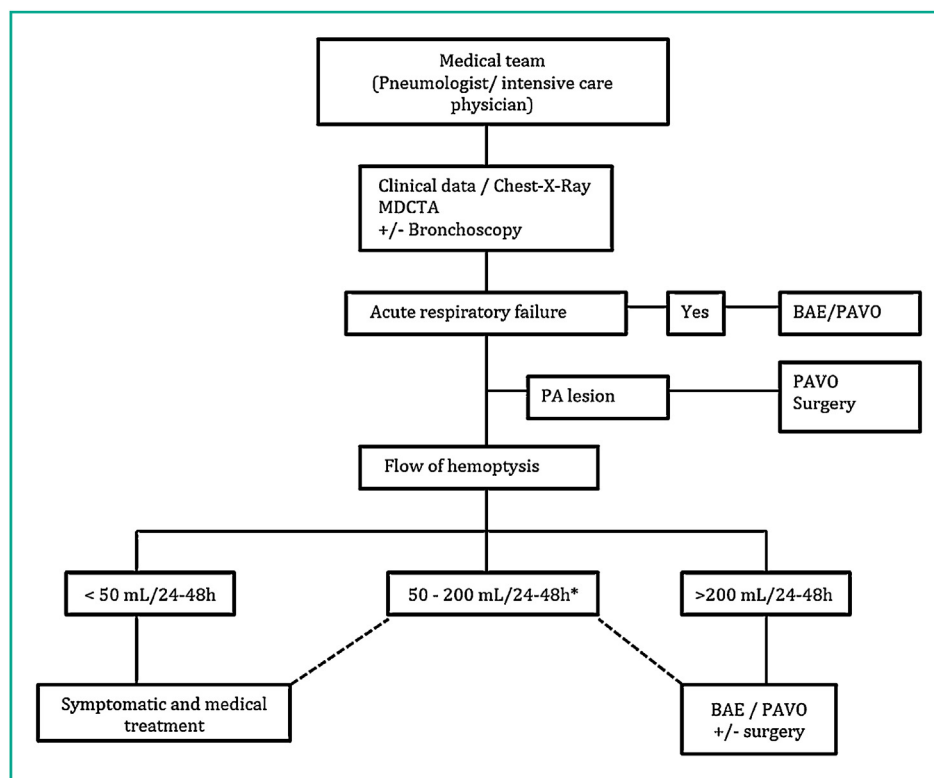
The two catheters used on first line are the JL4 (left coronary catheter) and the spinal catheter. Others may be required such as the left bronchial catheter, an AL1 or AL2

catheter and internal thoracic artery catheter, etc. The two left bronchial and left coronary catheters can "scrape" the floor of the aortic arch and catheterize the bronchial arteries arising from it.

By referring to MDCTA findings, arteries feeding the bleeding area are catheterized and an angiography series is then performed.

A microcatheter is recommended for safer embolization, although the risk of spasm and dissection of the bronchial arteries during catheterization with a microcatheter is higher, which prevent optimal embolization. If gentle risk-free embolization from the ostium of systemic arteries is possible (Fig. 7d–g), we recommend starting the embolization using the 5-F catheter. Early and repeated checks are required in order to avoid reflux of the embolization materials and to detect hazardous anastomoses as early as possible. These anastomoses may be unmasked when the hypervascularization is reduced during ostial embolization by the catheter, or more distally with the microcatheter.

The first line embolization materials are particles that are currently available in many sizes on the market, each of which has slightly different physical features. In our center, we use Embozene® 700 to 1300 microns, depending on the hypervascularization, systemic to pulmonary shunts and the lumen size of the catheter or micro-catheter. For a large systemic-pulmonary shunt, the use of a large particle size is required. Coils can be used, however, the operator remembers that proximal occlusion (mediastinal and



**Figure 10.** Chart indicating the management of life-threatening hemoptysis. The initial assessment includes a clinical assessment, a chest-X-ray (CXR), and a multidetector CT-angiography (MDCTA) ± bronchoscopy. The first line of treatment is interventional radiology or bronchial arteriography with embolization (BAE) or pulmonary artery vaso-occlusion (PAVO). \* In this situation, the indication for invasive treatment (BAE or PAVO) or medical treatment depends on the cause (aspergilloma with risk of recurrence by massive hemoptysis) or the underlying diseases (chronic respiratory failure with a risk of major respiratory impairment with a small amount of hemoptysis recurrence).

proximal hilar) should be avoided as there is a highly developed anastomotic network in the mediastinal and proximal region of the hilum of the lung (Fig. 3e, f). If occluded proximally, this anastomotic network can revascularize the vessel distal to the occlusion, making embolization less effective or even hazardous by closing a recognized and straightforward embolization approach. Coils should be reserved for permanent very distal obstruction, or if catheterization is difficult and/or hazardous (Fig. 9). The other embolization materials should be considered in occasional cases and need to be understood in advance of their use, in the same way as the liquids (Onyx®, Histoacryle®, etc.).

### Pulmonary artery vascular occlusion

In most situations, the approach via the right femoral vein is sufficient, using a 7- or 8-French introducer. In specific situations, such as a raised right hemidiaphragm and a past history of right middle and lower lobe lobectomies, the internal jugular approach is preferred for anatomical reasons. A guide catheter is highly recommended or may even be essential for at least three reasons: catheterization, changing catheters and optimal occlusion of the target pulmonary artery. The pulmonary arteries are wide and far from the puncture site with at least 2 curves before reaching the target, making direct catheterization difficult. The use of a guide catheter helps to lead the catheter (coaxial) using the double curve (the curve of the guide catheter and the curve of the coaxial catheter). Changing catheter is more straightforward with a guide catheter and in addition when occlusion is achieved using coils, the guide catheter offers two additional merits of compacting the coil and preventing pullback of the catheter, avoiding accidental occlusion of off-target arteries.

The occlusion should be as close as possible to the pulmonary artery lesion responsible for the bleeding. Ideally, for a pulmonary artery pseudoaneurysm, the occlusion should be made proximal and distal to the aneurysm, although this carries an increased risk of iatrogenic rupture. Proximal occlusion is sufficient for a distal, acute rapid process or in cancer. Conversely, in inflammatory and chronic infectious processes, particularly tuberculosis, sandwich occlusion is preferable in order to avoid the recurrence of the bleeding through the systemic vessels. The aim is to produce occlusion at the tip of the catheter without the need for distal embolization. Attention should be paid to the risk of rupturing a pseudoaneurysm during high-pressure injection or when a coil or plug is deployed in an irregular artery surrounded by necrosis. In decreasing order of frequency, the occlusion materials most often used are coils, plugs (vascular plug or microvascular plug), graft stents and Onyx®. The graft stent should be used for localized lesions when the artery has to be kept patent.

### Results and complications

Bronchial artery embolization provides immediate control (Table 1) of hemoptysis in over 80% of cases (65 to 92%) depending on the underlying disease [6,17,18]. Control is more effective with cryptogenic hemoptysis, bronchiectasis or active tuberculosis whereas this is less effective in aspergillosis or lung cancer. If an early recurrence occurs

**Table 1** Causes and results of endovascular treatment for massive hemoptysis managed in our center over 10 years (unpublished data).

Causes	Number of patients (n)	Success, n (%)
Tuberculosis (active and late complications)	189	158 (84)
Bronchiectasis	159	126 (79)
Cancer	149	91 (61)
Cryptogenic	126	106 (84)
Aspergilloma	48	21 (44)
Chronic obstructive pulmonary disease	29	19 (66)
Other	67	48 (72)
Total	767	569 (74)

(10 to 20% of cases), the immediate response should be a further review of the MDCTA looking for other bronchial systemic arterial conditions, either of atypical origin, or ectopic, a NBSA supplying the territory responsible for the bleed or alternatively a pulmonary source which was not initially seen. The use of systemic vasoconstrictors medication before bronchial artery embolization or of resorbable fragments (Gelfoam) during embolization is also a possible source of recurrence. In most cases a second angiography (Fig. 7h, i) usually enables the bleeding to be controlled again.

Long-term recurrence after bronchial arterial embolization occurs in 10 to 60% of cases and is due either to recanalization of the embolized vessels or to further hypervascularization when the cause of hypervascularization remains. This is common in aspergilloma and cancer [17,19,20].

The major complications of embolization are rare but serious and predominantly involve accidental embolization of the median anterior spinal artery which gives rise to the right and left superior intercostal arteries and are responsible for serious neurological events (Brown-Sequard syndrome and paraplegia) with an estimated incidence of 0.6 to 6.5% [18]. The other complications are necrosis of the esophageal or bronchial walls, myocardial infarction or more systemic spread because of an unstable catheter leading to reflux of the embolization materials into the aorta (ischemic stroke, gastrointestinal infarction, splenic hematoma, etc.). The possibility of splenic infarction should be investigated if a patient develops abdominal pain predominantly in the left hypochondrium together with shock and a fall in hemoglobin [21]. There is a risk of acute distal ischemia at the arterial puncture site in patients with atherosclerosis as a result of thrombosis (partly predisposed to by the length of the procedure and multiple angiography sessions for recurrences with several punctures). The incidence of these episodes is greatly influenced by operator experience [18,22] and some can be avoided by using hyperselective microcatheters, which in expert hands allow embolization beyond the origin of an esophageal branch or into a right bronchial artery well beyond the origin of the intercostal artery which may give rise to a median anterior



spinal artery in patients with a right broncho-intercostal trunk or during unstable catheterization. The most common complications of embolization are transient chest pain.

## Conclusion

MDCTA has become an unquestioned investigation in the pretreatment assessment of massive hemoptysis. It enables perfect visualization of the bronchopulmonary vascular tree and mechanisms responsible for severe hemoptysis. The first line treatment in the acute phase and in inoperative patients is endovascular.

### Take-home messages

#### General concepts

- Hemoptysis: blood arising from the infraglottic region.
- Hemoptysis, symptom (less than 50 mL/24–48 h): alarm signal for investigation into the cause.
- Hemoptysis, disease (serious) (volume over 200 mL/24–48 h): life threatening requires emergency specific treatment.

#### The use of multidetector CT-angiography

- Technique: optimal enhancement of all intra-thoracic vascular structures.
- Assesses the severity of the hemoptysis.
- Site of the bleeding: ground glass opacity or localized lung consolidation.
- Identifies the pulmonary artery mechanism for the bleeding (less than 10% of hemoptysis): necrosis, pseudoaneurysm, irregular pulmonary artery in the wall of a cavity or necrosis.
- Complete mapping of the bronchial and non-bronchial systemic arteries (over 90% of hemoptysis).
- Identifies the cause of the bleeding: tuberculosis, bronchiectasis, lung cancer (2/3 of causes). No cause found (cryptogenic hemoptysis) in 20 to 30% of cases.

#### Endovascular treatment

- Management in a specialized unit: intensive care and interventional radiology  $\pm$  thoracic surgery.
- Indication: at least one of the following criteria: respiratory tolerance (acute respiratory failure), pulmonary arterial mechanism and hemoptysis of over 200 mL/24–48 h.
- The approach (femoral artery or vein) depends on MDCTA findings.
- Embolization material: particularly microparticles (over 500 microns).
- The median anterior spinal artery (arising from the intercostal artery) must be looked for routinely and specifically during opacification of the right broncho-intercostal trunk; if it is present or there is a doubt as to its presence the use of particles is formally contraindicated and these should be replaced by occlusion with micro-coils.
- Embolization controls hemoptysis in 65 to 92% of cases depending on cause.

- Serious complications are rare (less than 5% in trained hands): cerebrovascular accident, spinal ischemia or esophageal necrosis.
- Early recurrence (10 to 20%): review the mechanism of the hemoptysis on MDCTA, further embolization (unembolized collateral, incomplete embolization of an artery, vasoconstrictor therapy, etc.).

## Clinical case

This 26-year-old man was referred for hemoptysis of 200 mL on one occasion 12 hours ago. Clinical examination revealed a patient in good general health, afebrile and without recent weight loss. He had no signs of respiratory distress and his respiratory rate was 14/min with an oxygen saturation of 98%. Laboratory investigations showed moderate microcytic anemia. His erythrocyte sedimentation rate and CRP were raised. A MDCTA was performed (Figs. 11–14).

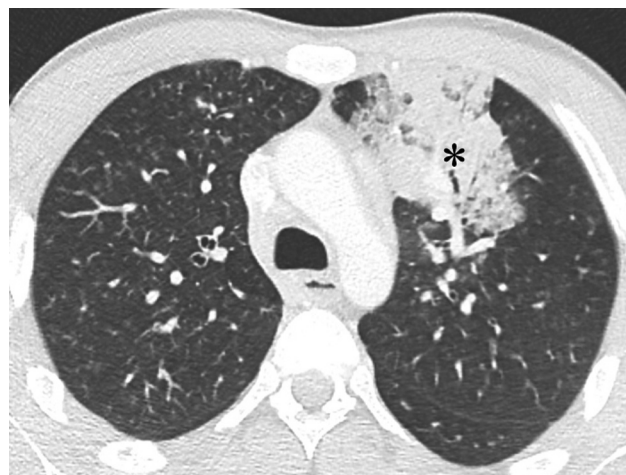


Figure 11. Axial views of a MDCTA in the parenchymal window.

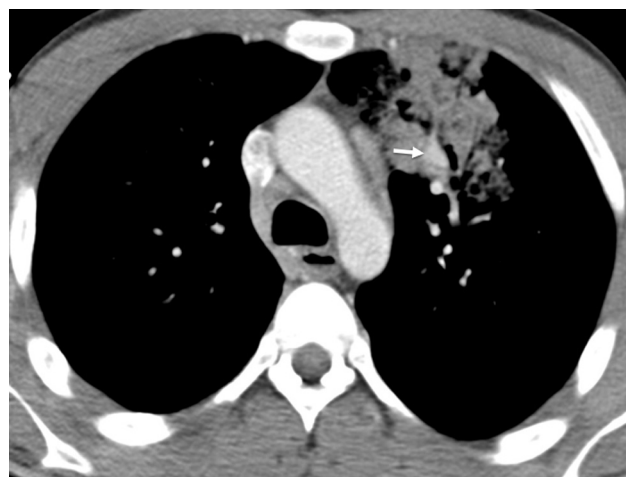
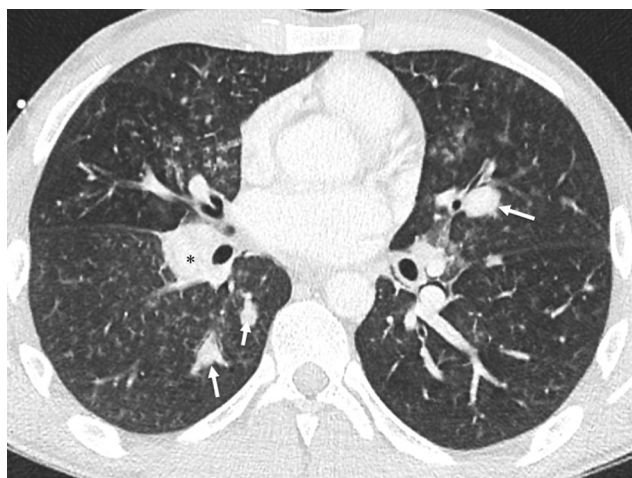
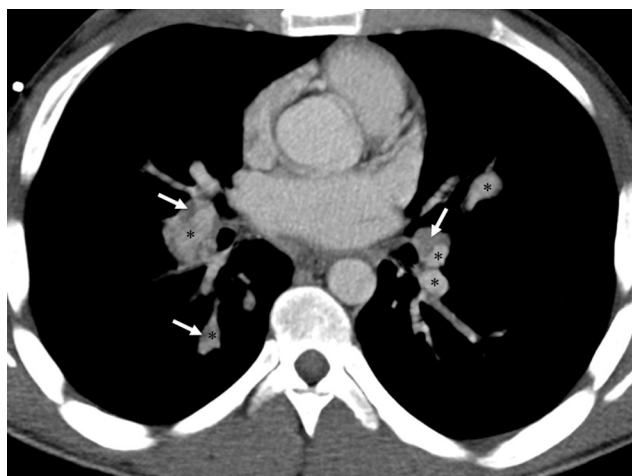


Figure 12. Axial views of a MDCTA in the mediastinal window.



**Figure 13.** Axial views of a MDCTA in the parenchymal window passing through the left atrium.



**Figure 14.** Axial views of a MDCTA in the mediastinal window.

## Questions

- 1) What is the site of the bleeding, describing the side, lobe and segment? List the CT evidence supporting your answer.
- 2) What is the mechanism of the bleeding?
- 3) What is the cause of the bleeding, giving evidence supporting it?
- 4) What are the arguments for emergency treatment?
- 5) In the event of endovascular treatment, describe the approach route, type of catheters and embolization materials.

## Answers

- 1) The site of the bleeding is on the left, in the culmen and specifically in the anterior segment of the culmen (S2). The CT-scan signs that localize the site of bleeding are the lung consolidation located in segment S2 on the left (Fig. 11, asterisk) combined with an aneurysmal appearance in the pulmonary artery within the consolidation (Fig. 12, arrow).

- 2) The mechanism of the bleeding is the rupture of a pulmonary artery aneurysm due to the presence of an irregular widening (Fig. 12, arrow) of the pulmonary artery (A2 left) within the consolidation (Fig. 11, asterisk).
- 3) The cause of the hemoptysis is Behçet's disease or Hughes-Stovin's syndrome. The evidence for this is:
  - non-radiological evidence:
    - a. young person in good general health and afebrile,
    - b. inflammatory syndrome with microcytic anemia and increased erythrocyte sedimentation rate and CRP (chronic inflammatory process);
  - radiological evidence:
    - a. the combination of pulmonary artery aneurysms (asterisks) and thromboses/inflammatory thickening of the wall of these aneurysms (arrows) clearly visible on Figs. 13 and 14. The Hughes-Stovin syndrome is similar to Behçet's disease although has no skin involvement (bipolar aphthosis). This is a purely vascular syndrome combining pulmonary artery disease (aneurysms and thromboses) and thromboses of the large vessels, particularly the inferior vena cava.
- 4) The arguments for emergency management are:
  - a. the hemoptysis volume of 200 mL/12 h: this is greater than the criterion of 200 mL/24–48 h,
  - b. the mechanism involves rupture of a pulmonary artery aneurysm; systemic vasoconstrictor therapy is ineffective on pulmonary artery lesions.
- 5) The approach route: the right femoral vein. If the inferior vena cava is thrombosed the right internal jugular or right basilic vein can be used.

Type of catheter: the use of a guide catheter is essential to ensure navigation and optimal embolization of the pulmonary arteries.

The abnormality to be treated: only the aneurysm in segment A2 of the left should be treated. The other abnormalities should be treated medically (immunosuppression and/or corticosteroids). The other abnormalities responded well to this medical treatment in this patient.

Embolization materials: either coils or a liquid material can be used. In this patient, we used Onyx® in order to lose as little lung parenchyma as possible.

## Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

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